



# EVALUATION OF IPV6 SERVICES FOR FUTURE AVIATION NETWORKS

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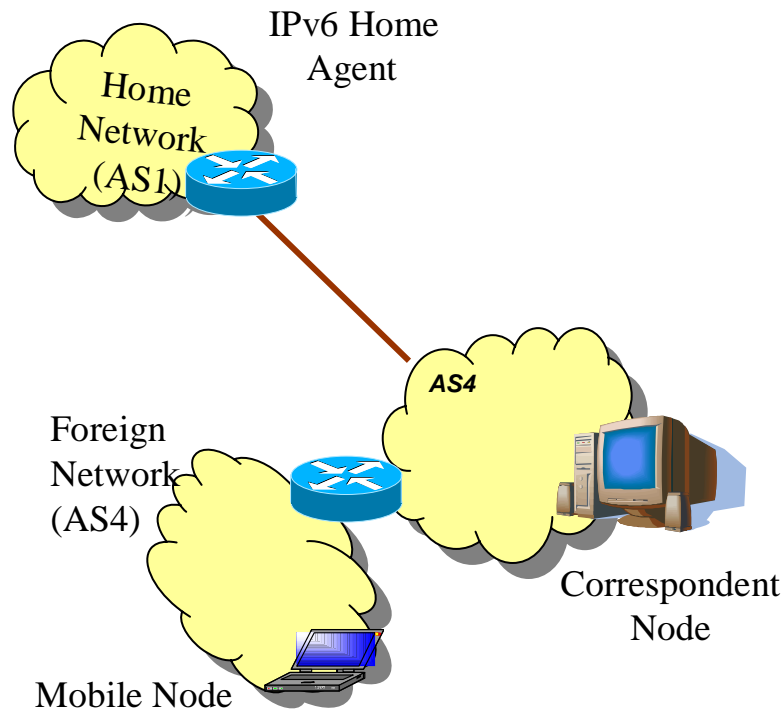
- **Motivation**
- **Objectives**
- **Mobile IPv6**
- **VoIPv6**
- **Security in IPv6 Networks**

- Lack of support for OSI standard from industry
- Evolution of ATN standards under International Civil Aviation Organization (ICAO)
- Similarities between TCP/IP and ATN protocol
- Exploration of the TCP/IP protocol suite for Communication, Navigation, and Surveillance (CNS) applications
- Internet Protocol for Aviation Exchange (iPAX) Working Group (under EuroControl) experimented migration of aviation backbone infrastructure from X.25 based networks to an Ipv6 networks
- Initiatives by IETF and IPv6 Forums

- **Deployment of various IPv6 services on IPv6 testbed at Computer Networks & Software, Inc. such as**
  - **Mobility**
  - **VoIP/IPv6**
  - **Network Security in IPv6**

- **ATN and IPv4 network supports mobility over a variety of mobile subnetworks**
  - **to several shortcoming, complex communication process, limited IPv4 addresses**
  
- **IPv6 Protocol has Mobility as built-in feature**
  - **Eliminates need of foreign agent required in MIPv4 due to use of stateless auto configuration and router discovery.**
  - **Provides source routing for optimization of routing directly from corresponding node to the mobile node**

# *MIPv6 – Operation and Implementations*

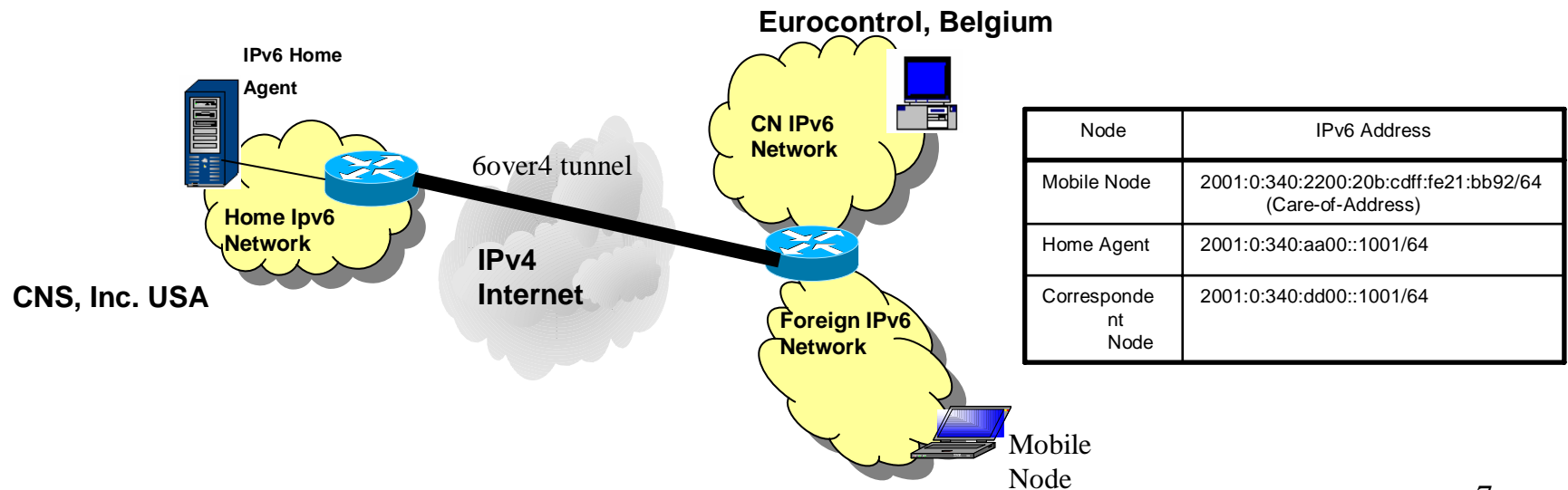


- **Movement Detection**
- **Care-of-Address Configuration**
- **Notification**
- **Binding Update**
- **Binding Acknowledgement**
- **Binding Request**

- **Linux:**
  - **MIPL Mobile IPv6 from Helsinki University of Technology (HUT) is an implementation for mobility support**
- **FreeBSD:**
  - **Based on INRIA's IPv6 code - Monarch Project from Rice Univ.**
- **Windows:**
  - **Lancaster University's LandMarc Project**

## *MIPv6 Test Setup*

- Test Mobile IPv6 over the internet with Eurocontrol
- Home agent setup at CNS using HUT's implementation
- Corresponding node (CN) setup at the Eurocontrol side
- CN reaches the Home Network (HN) through statically configured 6-in-4 tunnel
- Packet send to home address tunneled to mobile node in foreign network
- Route optimization tested – packet directed to mobile node directly



# MIPv6 – Trace output

<b>ICMPv6 (Request/Reply)</b>		12 4.041044	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		13 5.051054	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
<b>Router Advertisement in foreign network</b>		14 5.051089	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		15 3.087318	fe80::206:25ff:feab:99a2	fe80::2c0:f0ff:fe31:708	ICMPv6	Neighbor solicitation
		16 5.001160	fe80::2c0:f0ff:fe31:708	fe80::206:25ff:feab:99a2	ICMPv6	Neighbor advertisement
		17 7.118595	fe80::202:b3ff:fe33:4cc6	ff02::1	ICMPv6	Router advertisement
<b>Binding update to home agent</b>		18 7.118821	2004:0:340:40:206:25ff:feab:99a2	2001:0:340:aa02::1001	MIPv6	Binding Update
		19 7.837406	::	ff02::1:ffab:99a2	ICMPv6	Neighbor solicitation
		20 9.108013	fe80::202:b3ff:fe33:4cc6	ff02::1:ffab:99a2	ICMPv6	Neighbor solicitation
		21 9.108045	2004:0:340:40:206:25ff:feab:99a2	fe80::202:b3ff:fe33:4cc6	ICMPv6	Neighbor advertisement
		22 9.110378	2001:0:340:aa02::1001	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Binding Acknowledgement
		23 9.116579	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
		24 9.116677	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Home Test Init
		25 9.117473	2004:0:340:40:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Care-of Test Init
		26 9.118044	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		27 9.119115	2004:0:340:40:206:25ff:feab:99a2	2001:0:340:aa02::1001	ICMPv6	Mobile Prefix solicitation
		28 9.131295	2001:0:340:aa02::1001	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Binding Acknowledgement
		29 9.133943	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	MIPv6	Home Test
		30 9.136874	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
		31 9.136921	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		32 9.152858	2001:0:340:aa02::1001	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Binding Acknowledgement
		33 9.158848	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	MIPv6	Home Test
		34 9.163604	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
		35 9.163654	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		36 9.170079	2001:0:340:aa02::1001	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Binding Acknowledgement
		37 9.175913	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	MIPv6	Home Test
		38 9.181634	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
		39 9.181669	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		40 9.193994	2004:0:340:60::10	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Care-of Test
		41 9.194138	2004:0:340:40:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Binding Update
		42 9.199338	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	MIPv6	Home Test
		43 9.199469	2004:0:340:40:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Binding Update
		44 9.207128	2004:0:340:60::10	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Care-of Test
		45 9.207259	2004:0:340:40:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Binding Update
		46 9.225440	2004:0:340:60::10	2004:0:340:40:206:25ff:feab:99a2	MIPv6	Binding Acknowledgement
		.. ..	.....	...	.....	
		.. ..	.....	...	.....	
		.. ..	.....	...	.....	
		1821 21.107361	2004:0:340:40:206:25ff:feab:99a2	ff02::1:ff33:4cc6	ICMPv6	Neighbor solicitation
		1822 22.107364	2004:0:340:40:206:25ff:feab:99a2	ff02::1:ff33:4cc6	ICMPv6	Neighbor solicitation
		1823 24.235451	fe80::2c0:f0ff:fe31:708	ff02::1	ICMPv6	Router advertisement
		1824 24.235675	::	ff02::1:ff00:1001	ICMPv6	Neighbor solicitation
		1825 24.238246	2001:0:340:aa02::1001	ff02::1	ICMPv6	Neighbor advertisement
<b>Binding update</b>		1826 24.238267	2001:0:340:aa02:206:25ff:feab:99a2	2001:0:340:aa02::1001	MIPv6	Binding Update
		1827 24.238846	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Home Test Init
		1828 24.241208	2001:0:340:aa02::1001	2001:0:340:aa02:206:25ff:feab:99a2	MIPv6	Binding Acknowledgement
		1829 24.241231	fe80::206:25ff:feab:99a2	ff02::1	ICMPv6	Neighbor advertisement
		1830 24.241804	2001:0:340:aa02:206:25ff:feab:99a2	ff02::1	ICMPv6	Neighbor advertisement
<b>Binding Acknowledgement Back in home network</b>		1831 24.268065	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	MIPv6	Home Test
		1832 24.268229	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	MIPv6	Binding Update
		1833 25.090521	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
		1834 25.090555	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply
		1835 26.101084	2004:0:340:60::10	2001:0:340:aa02:206:25ff:feab:99a2	ICMPv6	Echo request
		1836 26.101117	2001:0:340:aa02:206:25ff:feab:99a2	2004:0:340:60::10	ICMPv6	Echo reply



# MIPv6 – Trace output

## Binding Update Message

```

Frame 18 (94 bytes on wire, 94 bytes captured)
Ethernet II, Src: aa:aa:03:00:00:00, Dst: 00:02:b3:33:4c:c6
Internet Protocol Version 6
  Version: 6
  Traffic class: 0x00
  Flowlabel: 0x000000
  Payload length: 40
  Next header: IPv6 destination option (0x3c)
  Hop limit: 255
  Source address: 2004:0:340:40:206:25ff:feab:99a2
  Destination address: 2001:0:340:aa02::1001
Destination Option Header
  Next header: Mobile IPv6 (0x3e)
  Length: 2 (24 bytes)
  PadN: 4 bytes
  Option Type: 201 (0xc9) - Home Address option
  Option Length : 16
  Home Address : 2001:0:340:aa02:206:25ff:feab:99a2 (2001:0:340:aa02:206:25ff:feab:99a2)
Mobile IPv6
  Payload protocol: IPv6 no next header (0x3b)
  Header length: 1 (16 bytes)
  Mobility Header Type: Binding Update (5)
  Reserved: 0x00
  Checksum: 0x5a0d
Binding Update
  Sequence number: 0
  1... .... = Acknowledge (A) flag: Binding Acknowledgement requested
  .1.. .... = Home Registration (H) flag: Home Registration
  ..1. .... = Link-Local Compatibility (L) flag: Link-Local Address Compatibility
  ...1 .... = Key Management Compatibility (K) flag: Key Management Mobility Compatibility
  Lifetime: 2500 (10000 seconds)
Mobility options
  PadN: 4 bytes
  
```

## Binding Acknowledgement

```

Frame 22 (94 bytes on wire, 94 bytes captured)
Ethernet II, Src: 00:02:b3:33:4c:c6, Dst: 00:06:25:ab:99:a2
Internet Protocol Version 6
  Version: 6
  Traffic class: 0x00
  Flowlabel: 0x000000
  Payload length: 40
  Next header: IPv6 routing (0x2b)
  Hop limit: 254
  Source address: 2001:0:340:aa02::1001
  Destination address: 2004:0:340:40:206:25ff:feab:99a2
Routing Header, Type 2
  Next header: Mobile IPv6 (0x3e)
  Length: 2 (24 bytes)
  Type: 2
  Segments left: 1
  Home Address : 2001:0:340:aa02:206:25ff:feab:99a2 (2001:0:340:aa02:206:25ff:feab:99a2)
Mobile IPv6
  Payload protocol: IPv6 no next header (0x3b)
  Header length: 1 (16 bytes)
  Mobility Header Type: Binding Acknowledgement (6)
  Reserved: 0x00
  Checksum: 0x5298
Binding Acknowledgement
  Status: Binding Update accepted (0)
  0... .... = Key Management Compatibility (K) flag: No Key Management Mobility Compatibility
  Sequence number: 0
  Lifetime: 58 (232 seconds)
Mobility options
  PadN: 4 bytes
  
```

- SIP and H.323 based signaling for establishing Voice over IPv6 calls
- SIP and IPv6
  - Text based protocol
  - True internet based, scalable, extendable to other IP capable devices ( e.g. gaming devices)
  - Dynamic configuration of end systems (user agents) and load balancing
  - Use of Anycast by user agents to send all SIP messages to registrar /outbound proxy
- SIP over IPv6 implementation for Linux
  - SIP Express Router (SIP registrar server, proxy)
  - Linphone and BonePhone ( IPv6 User agent)

## Registration server

- **VOCAL (Vovida Open Communication Application Library)** – IPv6 incompatibility (perl script)
- **SIP Express Router (SER)** – works as IPv4 and IPv6 server, reliable

## User agents

- **K-phone** – IPv4 with SER, IPv6 version not able to register
- **Linphone** – IPv4.IPv6 with SER, no voice data in IPv6 (bug in RTP stack)
- **6 Voice** - IPv6 user agent/SIP proxy capabilities
  - JMF, JRE, SIP stack provided by Linux
- **Other agents** - Windows messenger, LIPZ4 (IPv4, non- IPv6 compatible)

No. -	Time	Source	Destination	Protocol	Info
1	0.000000	10.1.2.15	10.1.1.3	DNS	Standard query MX f22.ip6
2	0.000219	10.1.2.10	10.1.2.15	ICMP	Destination unreachable
3	0.459913	10.1.2.15	10.1.1.3	DNS	Standard query A localhost
4	0.460134	10.1.2.10	10.1.2.15	ICMP	Destination unreachable
5	0.768579	2001:0:340:cc::3	2001:0:340:cc::1	SIP	Request: REGISTER sip:root@2001:0:340:cc::1
6	0.770401	2001:0:340:cc::1	2001:0:340:cc::3	SIP	Status: 200 OK (1 binding)
7	1.873130	fe80::202:b3ff:feb:ff07::5	fe80::202:b3ff:feb:ff07::5	OSPF	Hello packet

```

Request-Line: REGISTER sip:root@[2001:0:340:cc:0:0:0:1]:5060 SIP/2.0
Method: REGISTER
[Resent Packet: False]
Message Header
  Via: SIP/2.0/UDP [2001:0:340:cc::3]:5060;branch=z9hG4bK2414459628
  From: <sip:root@[2001:0:340:cc:0:0:0:1]>;tag=308245495
  To: <sip:root@[2001:0:340:cc:0:0:0:1]>;tag=308245495
  Call-ID: 902390262@2001:0:340:cc::3
  CSeq: 0 REGISTER
  Contact: <sip:(null)@[2001:0:340:cc::3]>
  max-forwards: 10
  expires: 900
  user-agent: oSIP/Linphone-0.12.1
  Content-Length: 0
    
```

Screen Shot Showing Trace of SIP Register Request

No. -	Time	Source	Destination	Protocol	Info
110	93.040054	2001:0:340:cc::3	2001:0:340:cc::2	ICMPv6	Neighbor advertisement
111	93.040786	2001:0:340:cc::2	2001:0:340:cc::3	SIP/SD	Request: INVITE sip:root@[2001:0:340:cc::2]
112	93.175001	2001:0:340:cc::3	2001:0:340:cc::2	SIP	Status: 100 Trying
113	93.175341	2001:0:340:cc::3	2001:0:340:cc::2	SIP	Status: 180 Ringing
114	95.179347	10.1.2.15	10.1.1.2	DNS	Standard query MX f22.ip6
115	95.179592	10.1.2.10	10.1.2.15	ICMP	Destination unreachable
116	98.168054	fe80::201:2ff:fe61::5	2001:0:340:cc::2	ICMPv6	Neighbor solicitation

```

Session Initiation Protocol
  Status-Line: SIP/2.0 100 Trying
  Status-Code: 100
  [Resent Packet: False]
  Message Header
    Via: SIP/2.0/UDP [2001:0:340:cc::2]:5060;branch=z9hG4bK2248423561
    From: <sip:root@[2001:0:340:cc:0:0:0:1]>;tag=72220493;tag=1035314875
    To: <sip:root@[2001:0:340:cc:0:0:0:3]:5060>
    Call-ID: 4222112742@2001:0:340:cc::2
    CSeq: 20 INVITE
    Content-Length: 0
    
```

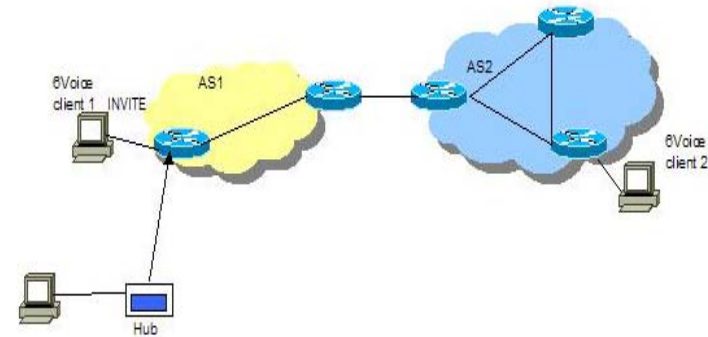
Showing Trace of Ringing Signal Received at the Caller

## VoIPv6 – Test Setup

### Test 1:

#### Between IPv6 Networks

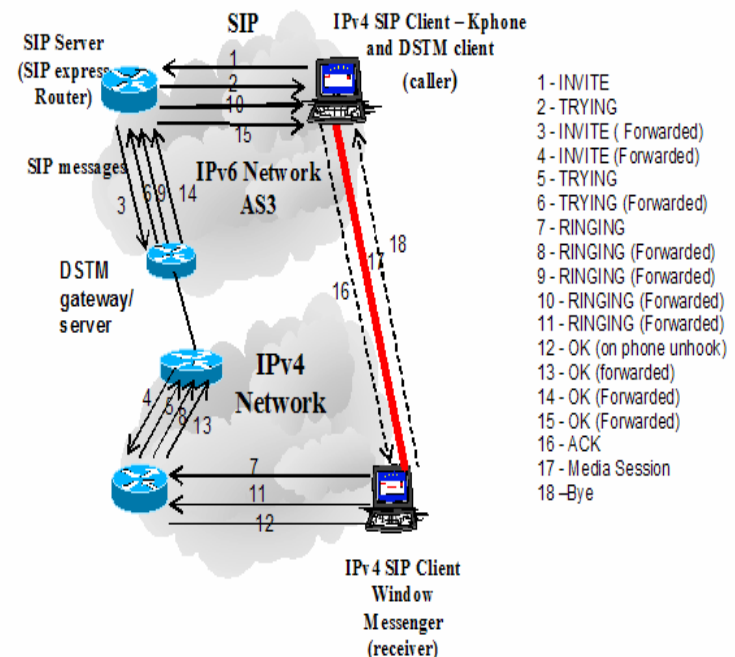
- 6 Voice setup in two domains
- Client 1 “invites” client 2
- Client 2 connected as a client of client 1
- Significant latency observed



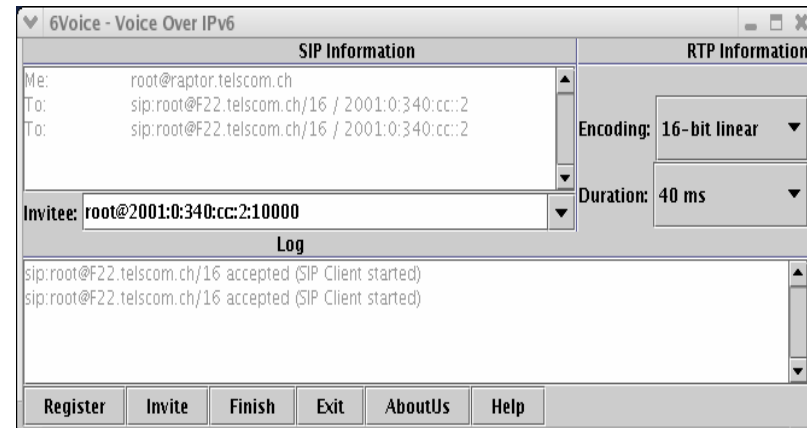
### Test 2:

#### VoIP application between IPv4 –IPv6

- IPv4 UA in IPv6 network (K-phone)
- IPv4 UA in IPv4 network (Windows Msngr)
- SIP express router as registration server
- DSTM based transition mechanism
- Acceptable latency values



- SIP signaling in 6Voice carried out using TCP
- Test 1: 6Voice demonstrated successfully it was observed that there was significant amount of latency (600ms) in the voice transmission (can be attributed to JMF bugs)
- Test 2: Between IPv4 network and IPv6 using SER showed latency of 100ms. Interoperability between UAs using SER illustrated



Screenshot of 6Voice GUI (client 1) after Connecting with the Other Client (client 2)

No. -	Time	Source	Destination	Protocol	Info
20	7.951306	fe80::202:b3ff:fee	ff02::5	OSPF	Hello Packet
21	10.029268	10.1.2.15	10.1.1.2	DNS	Standard query A F22
22	10.029428	10.1.2.10	10.1.2.15	ICMP	Destination unreachable
23	11.638570	2001:0:340:cc::2	2001:0:340:cc::3	TCP	10000 > 36415 [PSH, ACK] Seq=273
24	11.638525	2001:0:340:cc::3	2001:0:340:cc::2	TCP	36415 > 10000 [ACK] Seq=273
25	11.648501	2001:0:340:cc::3	2001:0:340:cc::2	TCP	36415 > 10000 [PSH, ACK] Seq=270
26	11.653531	2001:0:340:cc::2	2001:0:340:cc::3	TCP	10000 > 36415 [ACK] Seq=270
27	11.808612	10.1.2.15	10.1.1.2	DNS	Standard query MX f22.ip6
28	11.808778	10.1.2.10	10.1.2.15	TCP	Destination unreachable

0050	9e 9e 00 f3 cc 55 53 49	50 2f 32 2e 30 20 32 30	.....USI P/2.0 20
0060	30 20 4f 4b 0d 0a 46 72	6f 6d 3a 20 20 20 20 20	0 OK..Fr om:
0070	20 20 20 20 20 20 73 69	70 3a 72 6f 6f 74 40 66	sip:root@
0080	32 32 0d 0a 54 6f 3a 20	20 20 20 20 20 20 20 20	22..To:
0090	20 20 20 20 73 69 70 3a	6d 61 6e 6a 75 40 72 61	sip: manju@ra
00a0	70 74 6f 72 2e 74 65 6c	73 63 6f 6d 2e 63 68 0d	ptor.tel scom.ch.
00b0	0a 43 61 6c 6c 2d 49 44	3a 20 20 20 20 20 20 20	.Call-ID :
00c0	20 32 36 32 37 39 40 72	61 70 74 6f 72 2e 74 65	26279@r aptor.te
00d0	6c 73 63 6f 6d 2e 63 68	0d 0a 43 53 65 71 3a 20	lscom.ch. .CSeq:
00e0	20 20 20 20 20 20 20 20	20 20 31 20 49 4e 56 49	1 INVI
00f0	54 45 0d 0a 43 6f 6e 74	65 6e 74 2d 54 79 70 65	TE..Cont ent-Type
0100	3a 20 20 20 61 70 70 6c	69 63 61 74 69 6f 6e 2f	: appl ication/
0110	73 64 70 0d 0a 43 6f 6e	74 65 6e 74 2d 4c 65 6e	sdp..Con tent-Len
0120	67 74 68 3a 20 35 31 0d	0a 0d 0a 76 3d 30 0d 0a	gth: 51. ...v=0..
0130	63 3d 49 4e 20 49 50 36	20 46 32 32 2e 74 65 6c	c=IN IP6 F22.tel
0140	73 63 6f 6d 2e 63 68 2f	31 36 0d 0a 6d 3d 61 75	scom.ch/ 16..m=au
0150	64 69 6f 20 35 36 37 38	20 52 54 50 2f 41 56 50	dio 5678 RTP/AVP
0160	20 30 0a		0.

Trace Showing TCP Encapsulated SIP Message Interaction



## *Security in IPv6 Networks*

Requirements of a secure network:

- Authentication of data
- Privacy of data
- Data Integrity
- Non-repudiation of data

The solution???

IPSec – One size fits all

### **Features**

- Mandatory in IPv6 networks.
- Security provided by means of Authentication Header (AH) and Encapsulating Security Payload (ESP).
- AH – Provides integrity and authentication, no confidentiality.
- ESP – Provides confidentiality and optionally integrity and authentication.
- Key exchange is via the Internet Key Exchange protocol.

### **Modes of Operation**

Two modes of operation – tunnel mode, and transport mode.

Transport mode – Security for upper layer protocols when communication is directly between the endpoints.

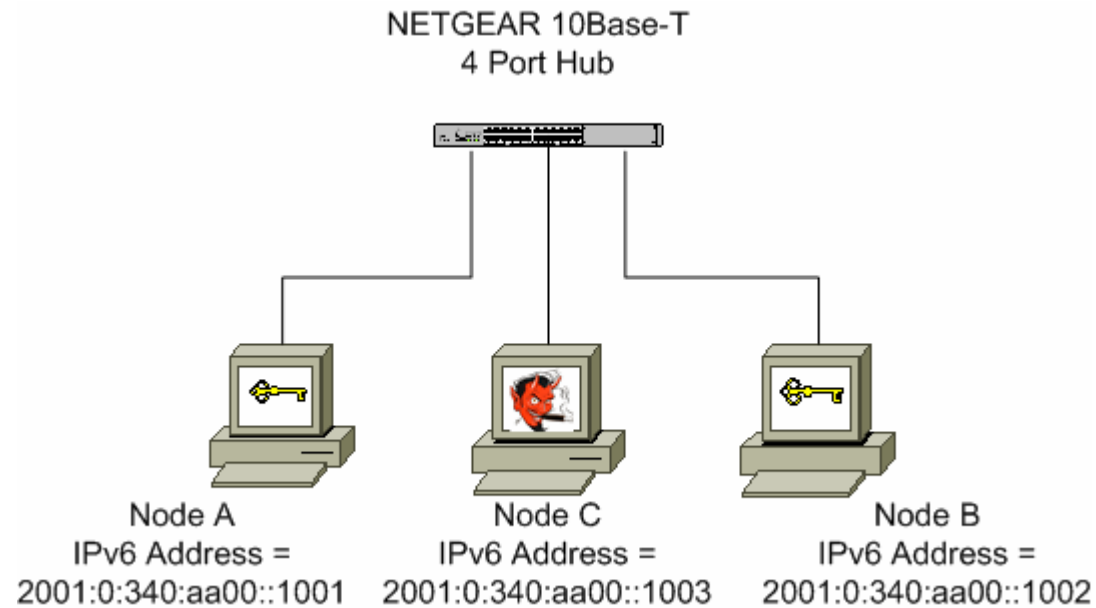
Tunnel mode – Security between two nodes having intermediate security gateways to unprotected networks. Entire IP datagram is secured via tunneling between the gateways.



### **Security Associations**

- Parameters that need to be shared between communication entities.
- Include keys for authentication and encryption, algorithms for encryption and authentication, algorithm specific parameters.
- Specified between a specific pair of host/gateways and with a specific direction.
- Saved in two databases; security association database (SAD) and security policy database (SPD).

## Implementation and Test topology



Test topology – IPSec over IPv6 (Transport Mode)

HTTPNoSecurity - Ethereal

File Edit View Go Capture Analyze Statistics Help

Filter:  Expression... Clear Apply

No.	Time	Source	Destination	Protocol	Info
1	0.000000	2001:0:340:aa00::1001	2001:0:340:aa00::1002	TCP	32805 > http [SYN] Seq=0 Ack=0 Win=5760 Len=0 M
2	0.000118	2001:0:340:aa00::1002	ff02::1:ff00:1001	ICMPv6	Neighbor solicitation
3	0.000339	2001:0:340:aa00::1001	2001:0:340:aa00::1002	ICMPv6	Neighbor advertisement
4	0.000449	2001:0:340:aa00::1002	2001:0:340:aa00::1001	TCP	http > 32805 [SYN, ACK] Seq=0 Ack=1 Win=5712 Le
5	0.000598	2001:0:340:aa00::1001	2001:0:340:aa00::1002	TCP	32805 > http [ACK] Seq=1 Ack=1 Win=5760 Len=0 T
6	0.008011	2001:0:340:aa00::1001	2001:0:340:aa00::1002	HTTP	GET / HTTP/1.1
7	0.008122	2001:0:340:aa00::1002	2001:0:340:aa00::1001	TCP	http > 32805 [ACK] Seq=1 Ack=415 Win=6432 Len=0
8	0.008770	2001:0:340:aa00::1002	2001:0:340:aa00::1001	HTTP	HTTP/1.1 200 OK (text/html)
9	0.008880	2001:0:340:aa00::1002	2001:0:340:aa00::1001	TCP	http > 32805 [FIN, ACK] Seq=328 Ack=415 Win=643
10	0.008881	2001:0:340:aa00::1001	2001:0:340:aa00::1002	TCP	32805 > http [ACK] Seq=415 Ack=328 Win=6432 Len
11	0.009468	2001:0:340:aa00::1001	2001:0:340:aa00::1002	TCP	32805 > http [FIN, ACK] Seq=415 Ack=329 Win=643
12	0.009579	2001:0:340:aa00::1002	2001:0:340:aa00::1001	TCP	http > 32805 [ACK] Seq=329 Ack=416 Win=6432 Len

Frame 1 (94 bytes on wire, 94 bytes captured)

Ethernet II, Src: 00:c0:f0:6b:bf:68, Dst: 00:0c:76:8e:58:9d

Internet Protocol Version 6

Version: 6  
 Traffic class: 0x00  
 Flowlabel: 0x000000  
 Payload length: 40  
 Next header: TCP (0x06)  
 Hop limit: 64  
 Source address: 2001:0:340:aa00::1001  
 Destination address: 2001:0:340:aa00::1002

Transmission Control Protocol, Src Port: 32805 (32805), Dst Port: http (80), Seq: 0, Ack: 0, Len: 0

Source port: 32805 (32805)  
 Destination port: http (80)  
 Sequence number: 0 (relative sequence number)  
 Header length: 40 bytes  
 Flags: 0x0002 (SYN)

0000 00 0c 76 8e 58 9d 00 c0 f0 6b bf 68 8e dd 80 00 ..v.X...k.h..  
 0010 00 00 00 28 06 40 20 01 00 00 03 40 aa 00 00 00 ..(.@...@..  
 0020 00 00 00 00 10 01 20 01 00 00 03 40 aa 00 00 00 .....@..  
 0030 00 00 00 00 10 02 80 25 00 50 0d 8f e6 a4 00 00 .....%.P.....  
 0040 00 00 a0 02 16 80 b7 d0 00 00 02 04 05 a0 04 02 .....P.....

Internet Protocol Version 6 (IPv6), 4C P: 12 D: 12 M: 0

Ethereal trace showing HTTP traffic with no security associations

# IPSec over IPv6

HTTPSecurity - Ethereal

File Edit View Go Capture Analyze Statistics Help

Filter:  + Expression... Clear Apply

No.	Time	Source	Destination	Protocol	Info
1	0.000000	2001:0:340:aa00::1001	ff02::1:ff00:1002	ICMPv6	Neighbor solicitation
2	0.000183	2001:0:340:aa00::1002	2001:0:340:aa00::1001	ESP	ESP (SPI=0x00000301)
3	0.000466	2001:0:340:aa00::1001	2001:0:340:aa00::1002	ESP	ESP (SPI=0x00000201)
4	2.998620	2001:0:340:aa00::1001	2001:0:340:aa00::1002	ESP	ESP (SPI=0x00000201)
5	8.997457	2001:0:340:aa00::1001	2001:0:340:aa00::1002	ESP	ESP (SPI=0x00000201)

Frame 2 (134 bytes on wire, 134 bytes captured)

Ethernet II, Src: 00:0c:76:8e:58:9d, Dst: 00:c0:f0:6b:bf:68

Internet Protocol Version 6

Version: 6  
 Traffic class: 0x00  
 Flowlabel: 0x00000  
 Payload length: 80  
 Next header: AH (0x33)  
 Hop limit: 255  
 Source address: 2001:0:340:aa00::1002  
 Destination address: 2001:0:340:aa00::1001

Authentication Header

Next Header: ESP (0x32)  
 Length: 24  
 SPI: 0x00000300  
 Sequence: 1  
 ICV

Encapsulating Security Payload

SPI: 0x00000301  
 Sequence: 1  
 Data (48 bytes)

```

0000  00 c0 f0 6b bf 68 00 0c 76 8e 58 9d 86 dd 60 00  ...k.h..v.X...
0010  00 00 00 50 33 ff 20 01 00 00 03 40 aa 00 00 00  ...P3.  ...@...
0020  00 00 00 00 10 02 20 01 00 00 03 40 aa 00 00 00  .....@...
0030  00 00 00 00 10 01 32 04 00 00 00 00 03 00 00 00  .....2. ....
0040  00 01 e0 75 30 1b f2 b0 7d e8 d2 ef b7 8b 00 00  ...u0... }.....
  
```

File: HTTPSecurity 750 bytes 00:00:1 ;P: 5 D: 5 M: 0

**Ethereal trace showing encapsulated HTTP traffic**

- IPv6 testbed helps in testing implementations that are available
- Services such as MIPv6, VoIP/IPv6 were setup based on popular implementations and analyzed
- Security in IPv6 was studied and analyzed based on IPSec